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SYSTEM ENGINEERING REPORT

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Alternate #

SUBJECT

COATING CONSIDERATIONS FOR SOFIA TELESCOPE

PROJECT SOFIA

DISTRIBUTION

Coating Considerations for SOFIA Telescope Mirrors

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The baseline optical system for SOFIA consists of a Cassegrain-type telescope with a dichroic tertiary mirror. The requirement for the two Cassegrain mirror coatings is high reflectivity from 0.3 to 1600 um, and low emissivity throughout the infrared. The reflectance of aluminum, gold, and silver are compared in Figure 1 from visible through mid-infrared wavelengths. Bare aluminum best satisfies the SOFIA requirement, but unfortunately is not durable when washed. On the other hand, it is relatively easy to clean and recoat a glass mirror with a bare aluminum coating.

Data in Figure 2 for the IRTF from Alan Tokunaga show the evolution of the 3.8 um emissivity of the telescope over a period of several years. The telescope has two mirrors coated with bare aluminum. After coating the emissivity is 8-9%. When dirt on the mirrors increases the emissivity to be about 19%, subsequent washing reduces it to only about 15%. Data not plotted in Figure 2 show that washing when the emissivity is 15% reduces it to about 12%. The expected emissivity of two freshly aluminized mirrors should be about 5% or less, based on data of Figure 1, and it isn't known why the measured values are never below 8% It appears that best performance can only be achieved by relatively frequent coating. It would certainly be desirable to find a coating that would reproduce the low emissivity of a freshly aluminized surface after multiple washings.

The requirement for the SOFIA beamsplitter is a low emissivity and high reflectance throughout the infrared (wavelengths longer than about 1 um), with visible transmission on the order of 50%. Figure 3 shows the performance of Liberty Mirror Company's IR-81-E coating, and a vacuum-evaporated gold-on-glass beamsplitter made at NASA Ames Research Center (ARC). The reflectance of bare aluminum from Figure 1 is reproduced for reference. The IR-81-E appears to be overcoated gold-on-glass, and withstands washing with little obvious degradation, while the ARC coating is quite fragile. The IR-81-E curves labelled 90 degrees are from the manufacturer; the other curves were measured at Ames at 45 degrees: I measured the visible and near IR reflectance and transmissionof the ARC beamsplitter, and Mike Haas measured the long wavelength reflectance and emissivity of a different sample, and of IR-81-E. The 100 um performance is summarized here:

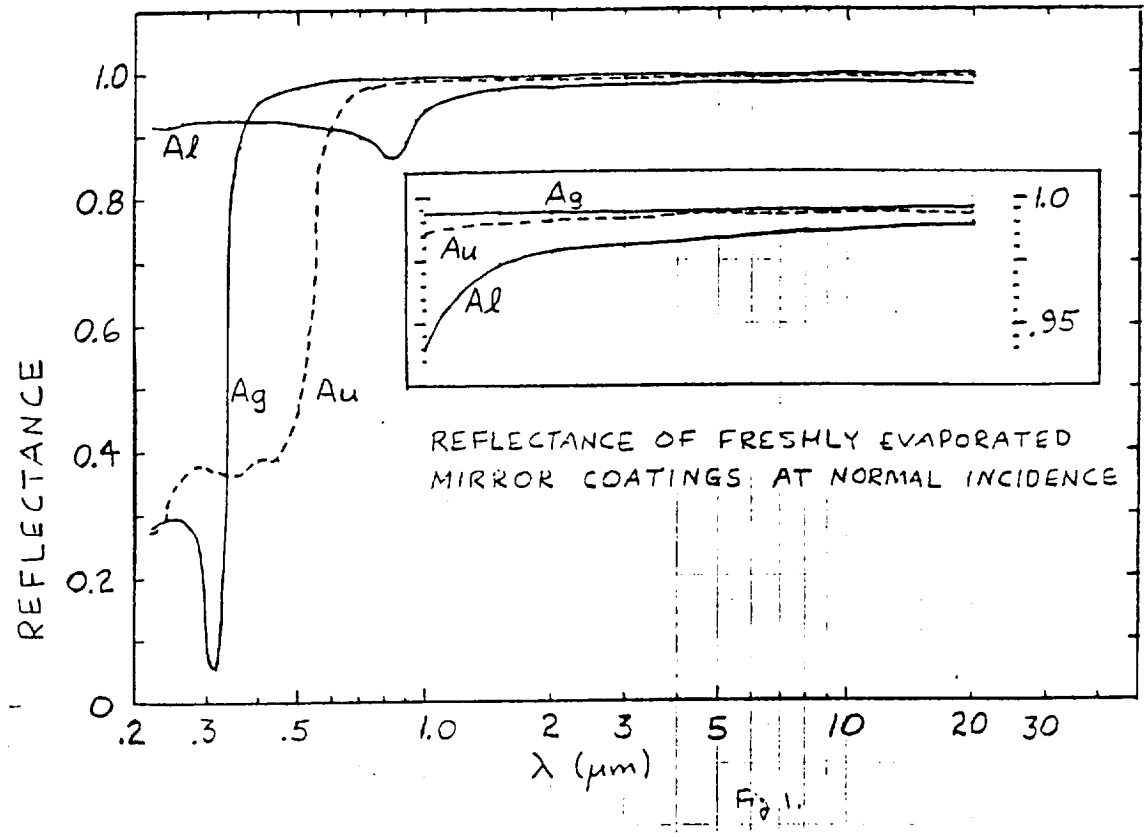
	reflectivity	emissivity
IR-81-E:	83%	15%
ARC:	91%	8%

The data show that the ARC coating is significantly superior to IR-81-E as a beamsplitter for wavelengths longer than at least 6 um. The 6 and 11 um measurements shown were done by Fred Witteborn and Jesse Bregman, and suggest the emissivity of IR-81-E is about 20% at 11 um. Ray Russell's measurement of 23% emissivity of IR-81-E at 4 um is shown, and he reports an emissivity of roughly 30% at 10 um.

Based on these results, it seems that the emissivity of the SOFIA

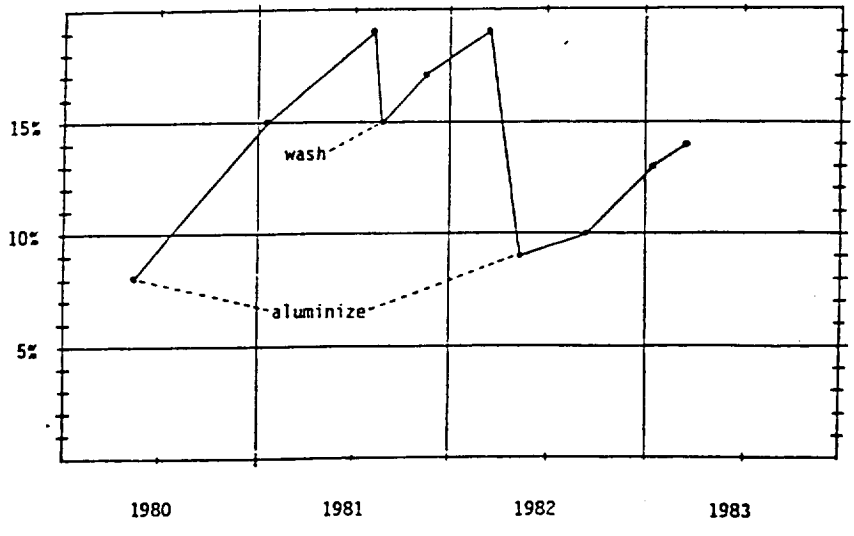
telescope mirrors and beamsplitter will be wavelength dependent, and will add up to roughly 20% under good routine operating conditions. We can further anticipate roughly 3% geometric obscuration by the telescope spider, but this contribution to the total emissivity can probably be reduced to less than 1%.

Additional work is called for in evaluating the performance of available beamsplitters over a wider wavelength range. Since the tertiary beamsplitter will probably be the largest single contributer to the emissivity, it will require more frequent replacement than the coatings on the primary and secondary. Keeping the mirrors clean will also be a high priority.



REFLECTANCE OF FRESHLY EVAPORATED MIRROR COATINGS AT NORMAL INCIDENCE

Fig 1.



IRTF TELESCOPE EMISSIVITY

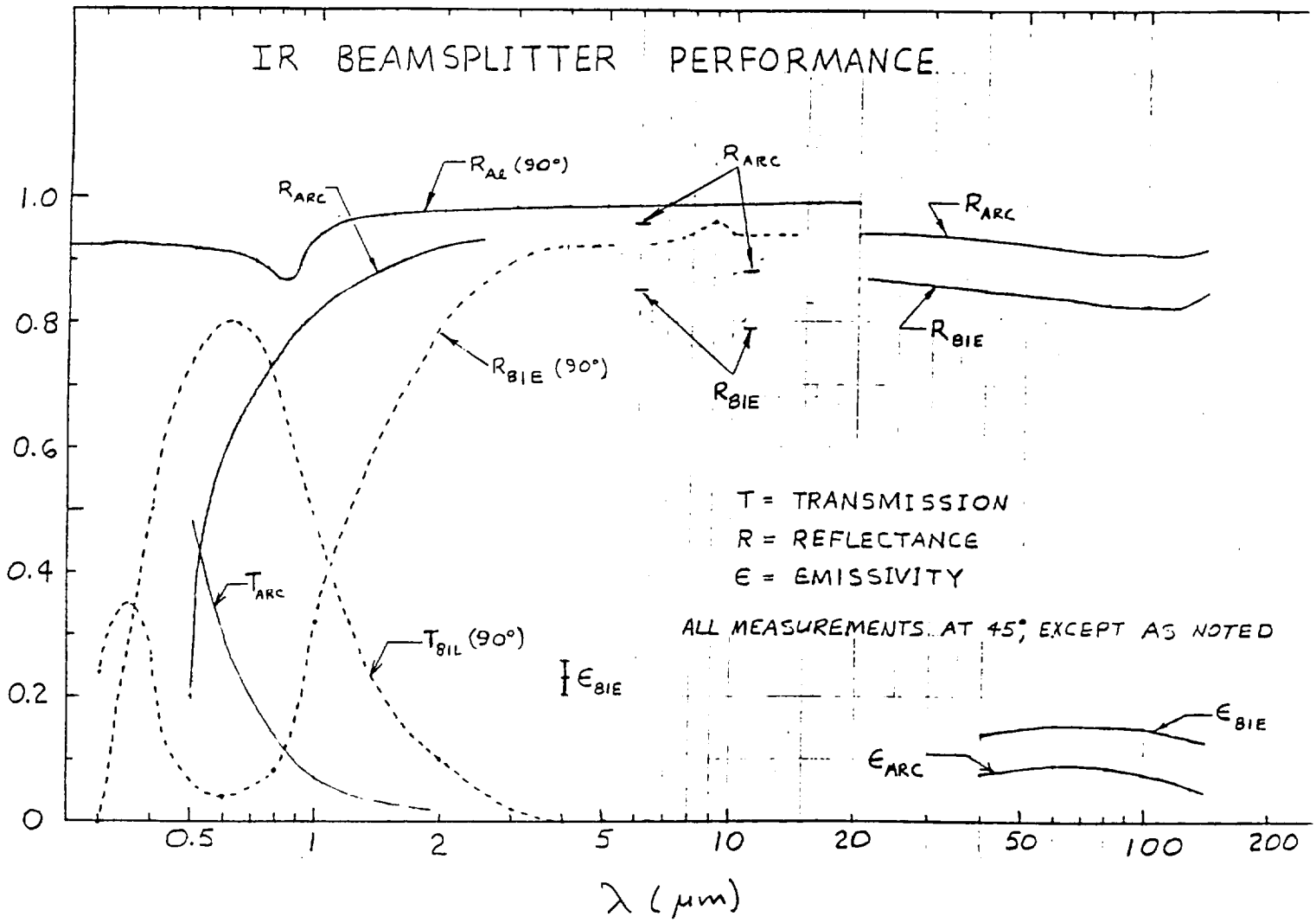

IR BEAMSPLITTER PERFORMANCE
1.0
0.8
0.6
0.4
0.2
0
0.5
1
2
5
10
20
50
100
200
λ (μm)
R_ARC
R_Al (90°)
R_ARC
R_ARC
R_BIE
R_BIE (90°)
R_BIE
T_ARC
T_BIL (90°)
ϵ_BIE
ϵ_BIE
ϵ_ARC
T = TRANSMISSION
R = REFLECTANCE
ϵ = EMISSIVITY
ALL MEASUREMENTS AT 45°, EXCEPT AS NOTED

Fig 3